Integration Processes in European R&D

A comparative spatial interaction approach using project based-R&D networks, co-patent networks, and co-publication networks

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wiw, Wien
14th March 2013

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Cumulative dissertation

Towards an integrated European Research Area? Findings from Eigenvector spatially filtered spatial interaction models using European Framework Programme data **with Scherngell T**	**Papers in Regional Science** (in press)
Embeddedness of European regions in EU funded R&D networks: A spatial econometric perspective **with Wanzenböck I. , Scherngell T.**	**Regional Studies** (submitted)
Integration Processes in European R&D: A comparative spatial interaction approach using project based R&D networks, co-patent networks and co-publication networks **with Scherngell T. , Brenner T.**	**Geographical Analysis** (submitted)
Flows of strong R&D collaborations in Europe: Evidence from a spatial interaction model **with Fichet de Clairfontaine A. , Fischer M.M.**	**Work in progress**

Motivation and Background

- The concept of the European Research Area (ERA) is intended to improve coherence and integration in European R&D,

- and to remove barriers for knowledge diffusion in a European system of innovation (see Hoekman et al. 2010,European Commission 2010),

- having in mind that innovation is the key for sustainable economic competitiveness, and collaboration in networks is crucial for innovation (see, for example, Romer 1990, Powell and Grodal 2005).

- Empirical evidence on integration processes in European R&D is scarce
    - Recent exceptions: Hoekman et al. (2010), Scherngell and Lata (2012)
    - geographical distance has a negative effect on co-publication activities and on project-based cooperation in the European Framework Programmes (FPs); for FP-networks this effect decreases over time

Objective of this Study

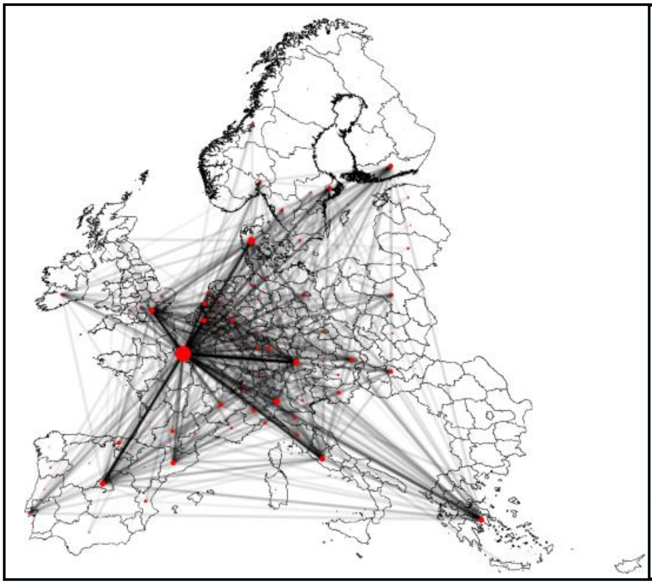
- is to estimate the integration progress in European R&D,
- by identifying the evolution of separation effects affecting the probability of cross-region R&D collaborations in European networks of R&D cooperation,
  - Separation effects: geographical, technological, economic, cultural and institutional barriers
  - The European networks of R&D cooperation are captured by FP-networks, co-patent-networks, and co-publication networks
- over the time period 1999-2006,
- using a panel version of the Negative Binomial Spatial Interaction Model.

Core Data Sets and Empirical Setting

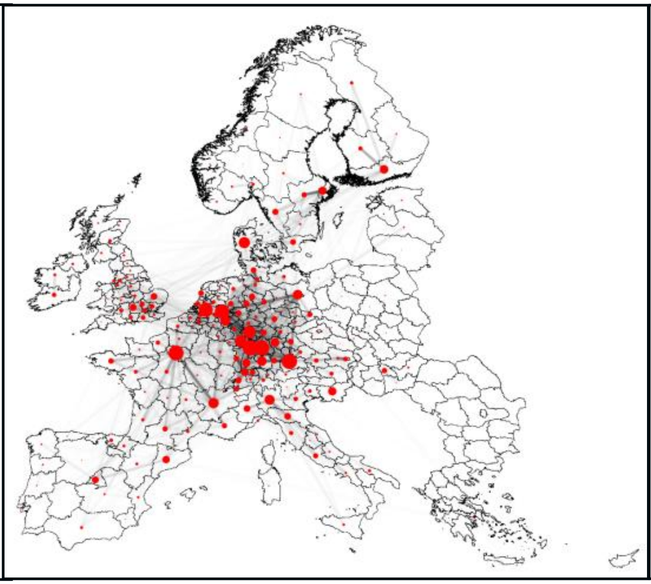
- EUPRO database→ developed and maintained by AIT; including systematic information on more than 60,000 collaborative research projects (FP1-FP7) and more than 60,000 participating organisations
- Regpat database→ provided by the OECD; containing all patent applications issued at the European Patent Office (EPO)
- Web of Science database→ provided by Thomson Reuters; comprising information on publications in more than 10,000 journals worldwide

- Study area is composed of $i, j = 1, ..., n = 255$ NUTS-2 regions (NUTS revision 2003) of the 25 pre-2007 EU member-states, as well as Norway and Switzerland.

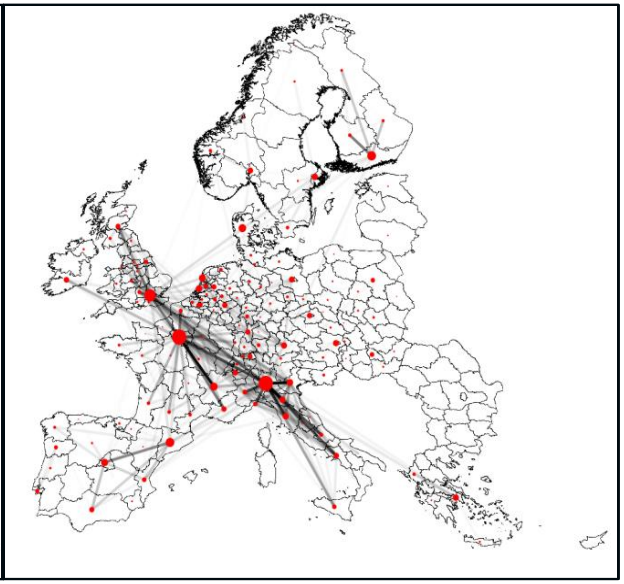
Spatial Distribution of the Cross-Region R&D Networks for 2006



within the FP-network



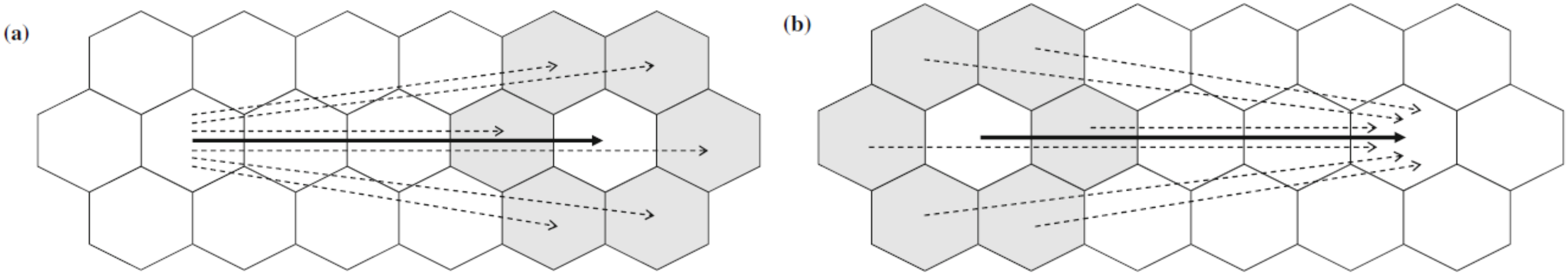
within the co-patent network



within the co-publication network

Spatial autocorrelation of Flows

- Spatial autocorrelation of flows is, for example, where flows from an origin may be correlated with other flows that have the same origin and similarly flows into a particular destination may be correlated with flows that have the same destination (Chun 2008).



- Theoretical and statistical motivation for taking into account spatial autocorrelation of flows (Scherngell and Lata 2012)

Test of Spatial Autocorrelation of Flows

Moran´s *I* test for spatial dependence

$$I_t = \frac{y_t' W^* y_t}{y_t' y_t} \qquad (1)$$

is defined by $W \otimes W$ where W is the n-by-n spatial weights matrix, with elements $w_{ij} = \begin{cases} 1 & \text{if } \; s_{ij}^{(1)} \leq s_{ig_{(i)}}^{(1)} \\ 0 & \text{otherwise.} \end{cases}$

is a vector of our observed collaboration flows at time t with $N=n^2$ elements $(y_{ijt}) = (y_{11t}, \ldots, y_{1nt}, y_{21t}, \ldots, y_{2nt}, \ldots, y_{n1t}, \ldots, y_{nnt})$

	Moran´ *I*							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
FP- Network	0.016^*	0.006^*	0.003^*	0.000	-0.001	0.007^*	-0.009	-0.001
Co- Patent Network	0.136^*	0.120^*	0.132^*	0.144^*	0.139^*	0.153^*	0.146^*	0.147^*
Co-Publication Network	0.068^*	0.063^*	0.067^*	0.065^*	0.069^*	0.068^*	0.072^*	0.068^*

*significant at the 0.001 significance level

The Spatial Interaction Modelling Perspective

$$Y_{ijt} = \mu_{ijt} + \varepsilon_{ijt} \qquad i, j = 1, \ldots, n; \quad t = 1, \ldots, T \tag{2}$$

Disturbance term

Expected mean interaction frequency

Random variable, corresponding to observed interactions y_{ij} between i and j

255 NUTS-2 regions

Time Period (1999-2006)

with

$$\mu_{ijt} = O_{it} \; D_{jt} \; S_{ijt} \tag{3}$$

$$O_{it} = o_{it}^{\alpha_1} \tag{4}$$

Origin function: Number of organizations in region *i* in time period *t*

$$D_{jt} = d_{jt}^{\alpha_2} \tag{5}$$

Destination function: Number of organizations in region *j* in time period *t*

$$S_{ijt} = \exp\left[\sum_{k=1}^{K} \beta_k \; s_{ijt}^{(k)}\right] \tag{6}$$

Separation measures

$k = 1$ geographical distance between region *i* and *j*

$k = 2$ neighbouring region effects

$k = 3$ country border effects

$k = 4$ language border effects

$k = 5$ technological distance between region *i* and *j*

The Random Effect Negative Binominal Specification

Random Effect Specification

$$\mu_{ijt} = \exp\left[\alpha_1 \log\left(o_{it}\right) + \alpha_2 \log\left(d_{jt}\right) + \sum_{k=1}^{K} ß_k s_{ijt}^{(k)} + \underset{\downarrow}{\gamma_{ij}}\right] \quad (7)$$

Random effect

Random Effects Negative Binomial specification

$$\Pr\left(y_{ij1}, \ldots, y_{ijT}\right) = \frac{\left(\prod_{t=1}^{T} \mu_{ijt}{}^{y_{ijt}}\right) \Gamma\left(\theta + \sum_{t=1}^{T} y_{ijt}\right)}{\left(\underset{\downarrow}{\Gamma(\theta)}\underset{\downarrow}{\prod_{t=1}^{T}} y_{ijt}!\right)\left[\left(\sum_{t=1}^{T} \mu_{ijt}\right)^{\sum_{t=1}^{T} y_{ijt}}\right]} Q_i \left(1 - Q_i\right)^{\sum_{t=1}^{T} y_{ijt}} \quad (8)$$

Gamma distribution

Variance of Gamma distribution

with

$$Q_i = \frac{\theta}{\theta + \sum_{t=1}^{T} \mu_{ijt}} \quad (9)$$

Spatial Filtering Specification

- Maximum likelihood estimation of the Poisson regression model assumes that all observations are mutually independent. Especially a violation of this assumption is induced by spatial network autocorrelation (Chun 2008, Griffith 2007).

- In the Spatial filtering approach employed, we follow Griffith (2007), and extract $\boldsymbol{E}_n$ eigenvectors from a modified spatial weights matrix of the form

$$\left(\boldsymbol{I}-\boldsymbol{\iota}\boldsymbol{\iota}'\tfrac{1}{n}\right)\boldsymbol{W}\left(\boldsymbol{I}-\boldsymbol{\iota}\boldsymbol{\iota}'\tfrac{1}{n}\right) \tag{10}$$

n-by-*n* identity matrix

n-by-*n* spatial weights matrix

n-by-1 vector of ones

- Eigenvectors serve as surrogates for spatially autocorrelated missing origin and destination variables (Tiefelsdorf and Boots 1995, Griffith 1996).

Accounting for spatial autocorrelation of flows and time effects

- Adjustment of Eigenvectors to the panel version of the spatial interaction model (Patuelli et al. 2011)
- A subset of $\boldsymbol{Z}_t$ time dummies captures aggregate year effects
- The application of the extracted origin and destination filters and time dummies leads to the spatially filtered panel version of the Negative Binomial spatial interaction model:

$$\mu_{ijt} = \exp\left[\underset{\substack{\downarrow \\ \textit{Origin spatial filters}}}{\sum_{q=1}^{Q} E_q \psi_q} + \alpha_1 \log\left(o_{it}\right) + \underset{\substack{\downarrow \\ \textit{Destination spatial filters}}}{\sum_{r=1}^{R} E_r \varphi_r} + \alpha_2 \log\left(d_{jt}\right) + \sum_{k=1}^{K} ß_k s_{ijt}^{(k)} + \underset{\substack{\downarrow \\ \textit{Time dummies}}}{\sum_{t=1}^{T} Z_t V_t} + \gamma_{ij} \right] \qquad (11)$$

Estimation Results: Random Effects Negative Binomial Spatial Filter Interaction Models

	FP-network	**Co-patent Network**	**Co-publication network**
Origin and destination variable $[\alpha_1] = [\alpha_2]$	0.955*** (0.001)	0.354***(0.003)	0.787***(0.002)
Geographical distance [ß$_1$]	-0.209*** (0.005)	-0.266***(0.005)	-0.204***(0.005)
Neighbouring region [ß$_2$]	0.229*** (0.021)	0.710***(0.017)	0.704***(0.020)
Country border effects [ß$_3$]	-0.063*** (0.016)	-1.058***(0.016)	-1.320***(0.017)
Language area effects [ß$_4$]	-0.164*** (0.013)	-0.740***(0.014)	-0.961***(0.014)
Technological Distance [ß$_5$]	-0.305*** (0.018)	-1.536***(0.023)	-0.340***(0.020)
Number of significant time effects	7	2	7
Number of origin spatial filters	32	39	34
Number of destination spatial filters	29	47	37
Constant $[\alpha_0]$	-9.799***(0.045)	-2.426***(0.041)	-8.568***(0.046)
Dispersion parameter	19.804***(0. 253)	2.722***(0.045)	2.746***(0.022)
LR Test (spatial filters)	1,335.17***	4,932.10***	11,866.40***
LR Test (random effects)	190,354.7***	30,634.3***	291,847.5***
LR Test (overdispersion)	281,497.1***	2232,645.8***	3452,263.3***
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Estimation Results: Time Interaction Terms

Time interaction Terms	**FP-Network**					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Geographical distance	-0.057***	-0.042***	-0.039***	-0.033***	-0.010***	-0.003 ***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Neighbouring region	0.171***	0.130***	0.089***	0.088***	-0.029**	-0.002
	(0.012)	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)
Country border effects	-0.083***	-0.073***	-0.074***	-0.060***	-0.018***	-0.000
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)

Time interaction Terms	**Co-Patent Network**					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Geographical distance	-0.030***	-0.016***	-0.014***	-0.007	-0.006	-0.008
	(0.005)	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)
Neighbouring region	0.104***	0.057**	0.113***	0.043	0.003	-0.024
	(0.029)	(0.029)	(0.029)	(0.024)	(0.028)	(0.028)
Country border effects	-0.087***	-0.059**	-0.065**	-0.063**	0.003	0.018
	(0.023)	(0.023)	(0.023)	(0.023)	(0.022)	(0.022)

Time interaction Terms	**Co-Publication Network**					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
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	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Neighbouring region	0.013**	0.019***	0.038***	0.044***	0.024***	0.045***
	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Country border effects	-0.035***	-0.042***	-0.112***	-0.128***	-0.031***	-0.064***
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	(0.012)	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)
Country border effects	-0.083***	-0.073***	-0.074***	-0.060***	-0.018***	-0.000
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Time interaction Terms	**Co-Patent Network**					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Geographical distance	-0.030***	-0.016***	-0.014***	-0.007	-0.006	-0.008
	(0.005)	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)
Neighbouring region	0.104***	0.057**	0.113***	0.043	0.003	-0.024
	(0.029)	(0.029)	(0.029)	(0.024)	(0.028)	(0.028)
Country border effects	-0.087***	-0.059**	-0.065**	-0.063**	0.003	0.018
	(0.023)	(0.023)	(0.023)	(0.023)	(0.022)	(0.022)
Time interaction Terms	**Co-Publication Network**					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Geographical distance	-0.012***	-0.024***	-0.039***	-0.032***	-0.007***	-0.014***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Neighbouring region	0.013**	0.019***	0.038***	0.044***	0.024***	0.045***
	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Country border effects	-0.035***	-0.042***	-0.112***	-0.128***	-0.031***	-0.064*****
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)

Conclusions

…in a policy context

- Geographical factors form lower obstacles for R&D collaborations in FP networks than in co-patent networks and co-publication networks
- Strong intra-national character of the co-patent network and co-publication network in contrast to the FP network
- Higher integration in the FP network than in the co-patent network and co-publication network.

…in a methodological context

- Methodologically the results provide evidence on the importance of considering spatial autocorrelation arising from origin and destination factors as shown by the higher model performance of the specification using spatial filters.

References

Scherngell, T. and Lata, R. (2012): Towards an integrated European Research Area? Findings from Eigenvector spatially filtered spatial interaction models using European Framework Programme data, submitted to *Papers in Regional Science* [status: forthcoming]

Scherngell, T. and Barber, M. (2011): Distinct spatial characteristics of industrial and public research collaborations: Evidence from the 5th EU Framework Programme, *The Annals of Regional Science* 46, 247-266

Barber, M.J., Fischer, M.M. and Scherngell, T. (2011): The community structure of R&D cooperation in Europe: evidence from a social network perspective, *Geographical Analysis* [forthcoming]

Paier, M. and Scherngell, T. (2011): Determinants of collaboration in European R&D networks: Empirical evidence from a discrete choice model, *Industry and Innovation* 18(1), 89-104

Scherngell, T. and Barber, M. (2009): Spatial interaction modelling of cross-region R&D collaborations. Empirical evidence from the 5th EU Framework Programme, *Papers in Regional Science* 88, 531-546 **(*awarded with the Martin Beckmann price for the best article published in PIRS 2009*)**

Accounting for spatial autocorrelation of flows and time effects

- Adjustment of Eigenvectors to the panel version of the spatial interaction model (Patuelli et al. 2011) in four steps:
  1. Extraction of subset of distinguished eigenvectors $\boldsymbol{E}_m$ on the basis of their Moran´s *I* values
  2. Adaption of the selected eigenvectors to the spatial interaction modelling framework; Origin candidate eigenvectors are obtained from $\boldsymbol{\iota} \otimes \boldsymbol{E}_m$; Destination candidate eigenvectors are drawn from $\boldsymbol{E}_m \otimes \boldsymbol{\iota}$
  3. Addition of Eigenvectors as explanatory variables to T= 9 cross-section versions of the Negative Binomial spatial interaction model; statistically significant Eigenvectors are identified
  4. Determination of those eigenvectors that are significant over all time periods; the resulting set of common origin and destination eigenvectors, $\boldsymbol{E}_q$ and $\boldsymbol{E}_r$, respectively, are defined as the time invariant spatial filter

- A subset of $\boldsymbol{Z}_t$ time dummies captures aggregate year effects

- The application of the extracted origin and destination filters and time dummies leads to the spatially filtered panel version of the Negative Binomial spatial interaction model:

$$\mu_{ijt} = \exp\left[\underset{\displaystyle\downarrow}{\sum_{q=1}^{Q} E_q \psi_q} + \alpha_1 \log\left(o_{it}\right) + \underset{\displaystyle\downarrow}{\sum_{r=1}^{R} E_r \varphi_r} + \alpha_2 \log\left(d_{jt}\right) + \sum_{k=1}^{K} ß_k s_{ijt}^{(k)} + \underset{\displaystyle\downarrow}{\sum_{t=1}^{T} Z_t V_t} + \gamma_{ij} \right] \qquad (12)$$

Origin spatial filters *Destination spatial filters* *Time dummies*

Deskriptive Statistics

	FP 1999	FP 2006	FP Mean	Co-patent 1999	Co-patent 2006	Co-patent Mean	Co-publication 1999	Co-publication 2006	Co-publication 200
Positive links									
Matrix elements	32,296	43,693	39,448	7,246	8,896	8,205	7,246	8,896	8,205
Sum	351,363	1015,907	685,336	195,080	268,498	238,127	195,080	268,498	238,127
Mean	10.88	23.25	16.95	26.92	30.18	28.95	26.92	30.18	28.95
Standard deviation	25.91	71.75	47.93	169.91	201.31	195.84	169.91	201.31	195.84
Min	1	1	1	1	1	1	1	1	1
Max	1,162	3,855	2,724	5,195	6,028	6,542	5,195	6,028	6,542
Intraregional links									
Matrix elements	255.00	255.00	255.00	255.00	255.00	255.00	255.00	255.00	255.00
Sum	7,991	18,941	13,999	89,038	122,450	109,628	89,038	122,450	109,628
Mean	37.51	81.99	63.36	349.16	480.196	429.910	349.16	480.196	429.910
Standard deviation	98.20	280.71	202.01	766.84	993.07	939.16	766.84	993.07	939.16
Min	1	1	1	0	0	0	0	0	0
Max	1,162	3,855	2,724	5,195	6,028	6,542	5,195	6,028	6,542
Interregional links									
Matrix elements	64,770	64,770	64,770	64,770	64,770	64,770	64,770	64,770	64,770
Sum	343,372	996,966	670,587	106,042	146,048	128,499	106,042	146,048	128,499
Mean	5.30	15.39	10.35	1.63	2.25	1.97	1.63	2.25	1.97
Standard deviation	18.14	57.42	36.79	22.65	29.91	27.71	22.65	29.91	27.71
Min	1	1	1	0	0	0	0	0	0
Max	623.00	2,642	1.652	2,240	2,875	2,909	2,240	2,875	2,909